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Experimental Study on a Solar-Assisted High Temper
Heat Pump

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Abstract

The performance of a solar-assisted high temperature heat pump for steam ge described in this experiment. The heat pump utilizes a vapor compression cy consists of compressor, preheater, internal heat exchanger, evaporator, expan and vertical steam generator. The main function of this system as a steam equipment needs a higher operating pressure than operating pressure of re cycles. Some limitation of this heat pump design are considered in this paper in avaibility of compressor. The design using a reciprocating compressor w pressure of 24 bar. In this condition, the choice of refrigerant is an impor Isobutane (R-600a) is used in this study for some reasons. Although it is fl isobutane has low saturation pressure, ozone friendly, and low global warmi A preliminary test of this solar-assisted heat pump was done to obtain pe characteristic of high temperature heat pump sub-system. The preliminary t steam from a boiler as a heat source. In the next experiment, heat from sol system will be used.

From the preliminary test, the output temperature of vapor could reach 120°C temperature of about 60°C. COP of the heat pump was 1.9 and maximum pr of the heat pump was 4.43. The water vapor flow out from steam generat kg minute. In this condition, the primary function of the heat pump to generate satisfied.

Keywords: *heat pump, high temperature, solar energy, isobutane, performance.*

1 INTRODUCTION

Concern for the environmental degradation will increase the utilization of clean energ as solar energy, is receiving greater attention for various applications using different te In the field of space and water heating, heat pump systems provide an efficient te energy efficient. This system also proved to contribute in the reduction of gases th warming.

...pumps offer a technology that can use heat sources that are available from the environment such ... soil, water, sun and other sources. By using less energy, heat pumps can increase the room and ... temperature. Comparison of some water heating systems in terms of initial cost, operating cost, ... efficiency of the system can be seen in Table 1 [6].

Table 1. Comparison of some water heating system

Types of water heater	Initial cost	Operating cost	Efficiency
Electric	Low	High	92%
Gas	Low	High	70%
Solar	High	Very Low	N.A
Heat Pump	Moderate	Low	300 – 600%

... are also shown to reduce emission of CO_2. Data in 1997 showed the total global CO_2 ... by 22 billion tons [5]. Heating room produces 30% of CO_2 emissions, while industrial ... producing emissions by 35%. With the use of heat pump can reduce 31% CO_2 emissions from ... sector compared with the use of heating using oil-fired boilers. In 2002 total CO_2 ... savings with heat pump is 1.2 billion tons, this means that approximately 6% of total CO_2 ... These emission reductions are the biggest reductions that can offer by a single technology. ... increase in power efficiency and heat pumps can reduce 16% CO_2 emissions.

... advantages in heat pumps compared with other systems, the development of heat pump ... as a heating system has good prospects. Heat pump technology found in cold season ... more for room and water heating, whereas for the tropics country such as Indonesia, ... of heat pump is for water heating and drying systems.

... of heat pump are now available on the market, the vapor compression type using ... refrigerant such as R-22, R114, R-407 and R-134a. Because the system is mostly used ... the heat pump ability is still limited primarily to the water out temperature was ... °C [12]. Several systems have been tried like EVI cycle (*Enhanced Vapor Injection*) ... produce output stream temperatures up to 90°C [14].

2 HIGH TEMPERATURE HEAT PUMP

... heat flows from a higher temperature to lower temperature. By using a small amount of ... flow direction can be reversed by using heat pump technology. This technology is useful ... move heat from natural sources such as air, water, soil, waste heat or solar energy into ... used by the commercial and industry sector.

... two main types of heat pumps, the vapor compression heat pump and absorption heat pumps. ... the heat pumping can be achieved through a variety of thermodynamic cycles and ... as the Stirling Cycle, Vuilleumier Cycle, sorbtion solid-vapor system, hybrid systems ... processes. In consideration of the higher COP, this research is focused on the ... of vapor compression heat pump.

... vapor compression heat pumps started to be developed in the late 19th century and began ... at the beginning of the 20th century. The main components of this cycle are the ... expansion device and two heat exchangers, each of which serves as the evaporator and ... condenser. In a few CO_2 heat pump systems, a condenser function is replaced by cooler gas.

High temperature heat pump is used utilizing solar collector system as a source of heat and ... generators to replace the function of a condenser. The scheme of this system is shown in Figure ... system is divided into two parts, namely the sub-solar heating system that is used as a heat source ... heat pumps, and the second is a heat pump sub-system.

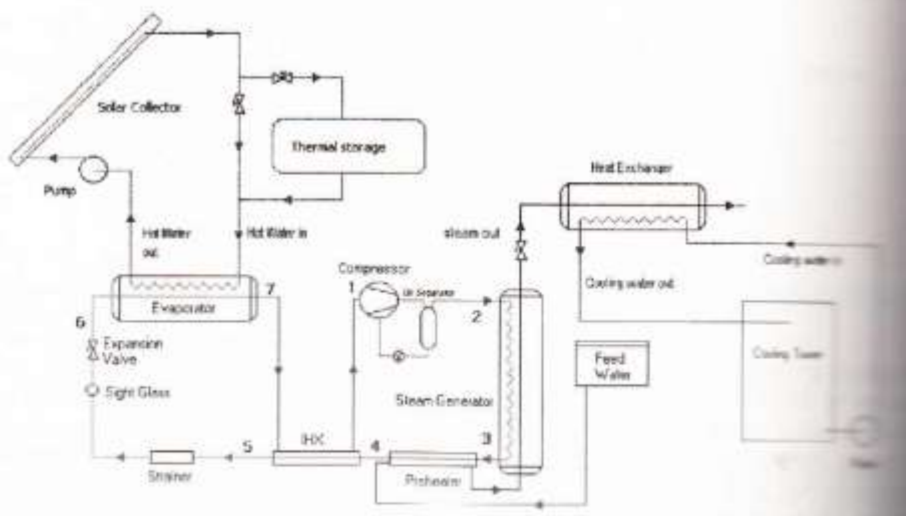


Figure 1 High temperature heat pump assisted solar energy heating

Evaporator transfer energy from the heat source of the sub-solar heating systems to ... pump. The flow of refrigerant from the evaporator through an internal heat ... compressed in the compressor to high pressure and temperature. Refrigerant then ... steam generators, and then transferred to the flow of water that flows through the ... will turn it into steam flow. Before entering the steam generator, water flows ... which will increase the initial temperature of the water from the initial conditions.

Several studies using heat pumps in combination with other heat sources has also ... Odeh et.al [10] did research on the combination of heat pump which uses ... multiplier effect on the evaporator. Refrigerant used is R-134a and the water is ... fluid in solar energy systems. Double effect evaporator is obtained by combining ... evaporator from the water and air around. Increasing water flow rate in the evaporator ... heat released by the condenser as well as an increase input water temperature ... increase the heat released by the condenser and COP of the heat pump.

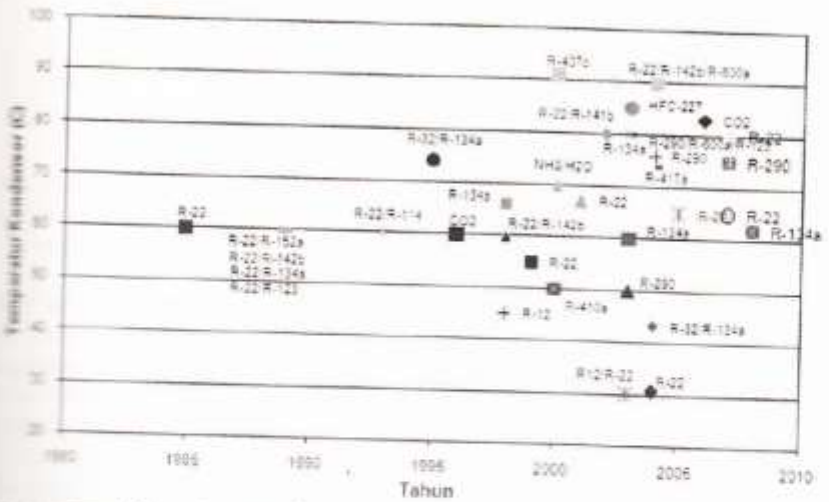
Heat pump combined with solar energy used by Yumrutas and Kaska [15] for the ... heating. The system using refrigerant R-22 and thermal storage using water as ... is about 2.5 for a lower storage temperature at the end of a cloudy day and it is about ... storage temperature at the end of a sunny day, and it fluctuates between these values ... Also, COP_S turns out to be about 15–20% lower than COP_{HP}.

Chaichana et.al [16] compared the performance of refrigerant R-22 to the hydrocarbon ... 290, R-600, R-600a, R-1270), R-717 and R-744 in the solar-boosted heat pump. ... the R-717 has more advantages when compared with other refrigerant. Regardless ... with the material, R-717 can use R-22 compressor. Moreover, with a high ... charged is also smaller. The weakness of R-717 lies in its toxic, corrosive to copper ... temperature reach 200°C, which may result in the decomposition of lubricating oil ...

... directly substituted into the R-22 systems with little modification for safety considerations, ... the COP system will be slightly reduced compared to R-22.

... [4] researched the various refrigerants as a substitute for CFC refrigerant, refrigerant HFE-134 ... promising for use in high temperature applications as a substitute for CFC-114. HCFC-123 ... replacement CFC-11, while HFC-245ca and HFC-143 is used as a substitute for CFC-11 for ... long term.

... various studies that heat pumps currently available, the presence of vapor compression heat ... from 1985 to 2008 can be displayed in a diagram form as in Figure 2. This diagram shows the ... types of refrigerant used in heat pumps so far and achieved a condenser temperature both pure ... and refrigerant mixtures. The maximum temperature of the condenser heat pump is located ... the range of 90°C.



... Diagram of the existence of vapor compression heat pump from the year 1985 - 2008

... the study also showed that the presence of heat pumps as a producer of steam has not ... variety of benefits that have heat pumps and solar energy combined with a heat source at ... the heat pump as the assessment of steam-producing potential to be developed.

4 EXPERIMENTAL RESULT

... test on the sub-heat pump system is done by using the input heat from the steam ... boilers. Steam is passed into heat exchanger so that heat input to the evaporator can be ... Testing is done by using isobutane (R-600a). Control of hot water flow in the evaporator is ...

... on the sub-heat pump system shown in Figure 3. From the temperature graphs that occur ... indicates that the condenser temperature increases when evaporator is given heat from ... The maximum temperature of refrigerant reaches 140°C after 95 minutes run ... the same time the water in the steam generators are also experiencing a phase change ... formed at the temperature source 75°C. The maximum steam temperature generated ... reaches 120°C with a flow rate reaches 0.11 kg / min. This sub-system reaches ... achieved in accordance with the conditions of temperature refrigerant into steam ... 120°C.

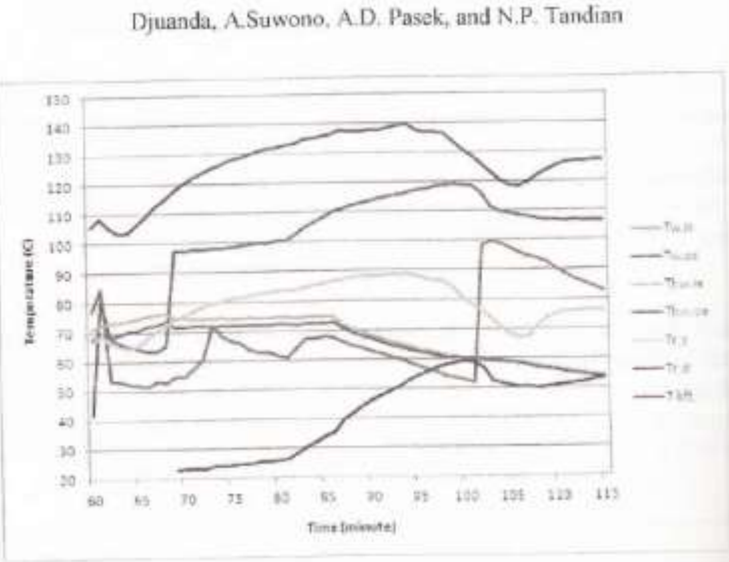


Figure 3 Temperature history of heat pump

Another point of concern is lift temperature generated by the heat pump system. Lift [illegible] defined as the temperature difference between the output generated steam generators [illegible] the evaporator (Tr,os - Thw,ie). The results of testing on the system can be seen in Figure [illegible]

When given the heat from the evaporator boiler, lift temperature will decrease. [illegible] increase in water temperature input to the evaporator while the temperature of [illegible] generator is not a comparable increase. At the time of steam began to form in the [illegible] increase of very high temperature. The maximum lift temperature that can be [illegible] then decreased with increasing temperature input in the evaporator and then [illegible] temperatures of about 50°C.

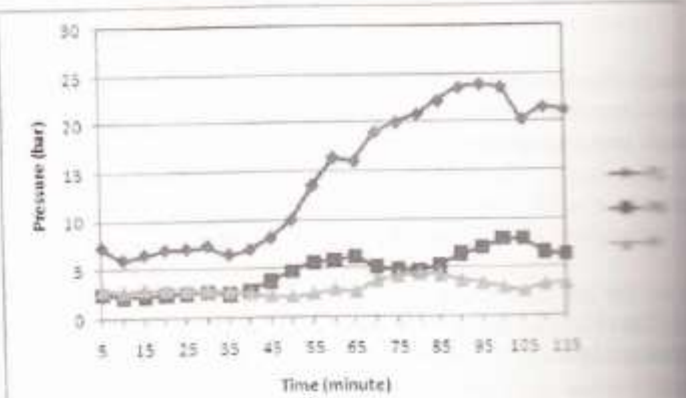


Figure 4 Pressure and ratio of pressure of the heat pump

Increasing the temperature of the system itself also affects the pressure [illegible] Pressure on the steam generator also experienced significant improvement [illegible] evaporator heat. The maximum pressure achieved by the steam generator reaches [illegible] respectively in the evaporator. Pressure ratio which can be obtained from the [illegible]

... seen from Figure 4. The ratio of the maximum pressure that can be achieved by a heat pump ... using isobutane reaches 4.43, whereas the minimum ratio reached 2.13.

... boiler for heating source, simulation of solar assisted high temperature heat pump was done. ... from boiler flow into the heat exchanger firstly and then transferred to the flow of water ... evaporator. The amount of heat input to the evaporator is set by adjusting the mass flow into ... evaporator. Settings needed in order to simulate the heat input from solar collector. Variations in ... to the evaporator and the system performance can be seen in Figure 5.

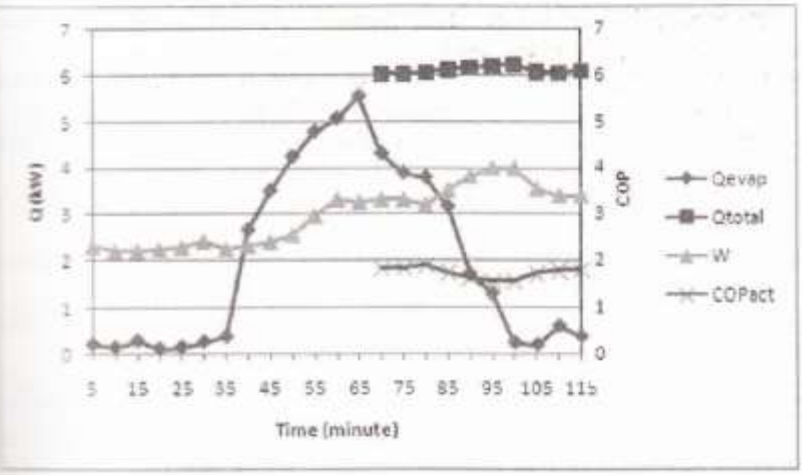


Figure 5 Performance of heat pump

... heat input to the evaporator was likes sine graph. Where there is an increase in heat until ... the peak point and then declined again. Maximum heat input to the evaporator reaches 5.6 ... the graph it can also be seen that along with increasing the heat input, compressor power ... and reached a maximum of 4 kW. While the maximum heat output of the steam ... pre-heater reaches 6.24 kW. With the output power would be obtained for the COP ... The low COP of the system, because still many losses that occurred in the heat pump ...

5 CONCLUSION

... has been used as a working fluid at high temperature heat pump. By providing ... the evaporator in order to change the lift temperature heat pump can be increased up to ...

... the compressor output pressure also increased reaching 300% compared to before the ... the evaporator. And the ratio of the maximum pressure achieved by the heat pump to ... this research, isobutane is potential refrigerant for heat pump application at high ...

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REFERENCES

[1] Brunin, O., M. Feidt and B. Hivet. "Comparison of the working domains of some compression heat pumps and a compression-absorption heat pump", *Int. J. Refrigeration*, 20:5, 30[illegible], 1997.

[2] Coelho, L.M.R., *Basics of Heat Pump Technology*, Workshop Groundhit, Brussel, 200[illegible]

[3] Departemen Energi dan Sumber Daya Mineral. *Kebijakan Pengembangan Energi [illegible] dan Konservasi Energi (Energi Hijau)*, Jakarta, 2003.

[4] Devotta, S. "Alternatif heat pump Working fluids to CFCs", *Heat Recovery Systems & CHP*, [illegible] 3, 273-279, 1995.

[5] Halozan, Hermann, Gilli, Paul Viktor, "Heat pump for different world region-Now and in the future", *18th World Energy Congress*, 2002.

[6] Hawaiian Electric Company Inc. *Guide to Heat Pump Water Heating for Condominium, Comercial, and Institutional Facilities*, Energy Services Department, 2003.

[7] IEA Heat Pump Centre. "Norwegian heat pump sales boom", *IEA Heat Pump Centre [illegible]* 1:4, 7, 2003.

[8] Kenisarin, M, Khamid,M. "Solar energy storage using phase change materials", *[illegible] Sustainable Energy Review*, 2006.

[9] Narodoslawsky, M., , F. Windisch, F. Mose. "New compression heat pump media for [illegible] high temperature aplication", *Heat Recovery system & CHP*, 8:1, 23-31, 1998.

[10] Odeh, S., Salem N., Bilal A. "Performance evaluation of solar-assisted double-tube [illegible] heat pump system", *Int. Comm. Heat Mass Transfer*, 31:2, 191 – 201, 2004

[11] Sarkar, J., Bhattacharyya, S., Gopal, M.R. "Natural refrigerant-based subcritical and [illegible] cycles for high temperature heating", *International Journal of Refrigeration*, 1-8, 200[illegible]

[12] Smith, F.J., Meyer JP. *Potential of Non-Zeotropic Refrigerant Mixture as Working [illegible] Hot Water Heat Pumps, Research Group for Heating and Cooling Technology, [illegible]* Energy, Auckland Park, South Africa. 2006.

[13] Ure, Z., "Positive temperature eutectic (PCM) thermal energy storage systems", *[illegible] Congress of Refrigeration*, Washington DC. ICR0606, 2003.

[14] Viessmann. *Technical Series Heat Pumps*, 2004.

[15] Yumrutas, R., Onder, K., "Experimental investigation of thermal performance of a [illegible] heat pump system with a thermal storage", *International of Journal Energy Research*, [illegible] 175, 2004.

[16] Chaichana, C., Aye L., Charters W.W.S., "Natural Working Fluids for Solar-boosted [illegible]", *International Journal of Refrigeration*, 26, 1-8, 2003.